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Cubic Foot/Weight Scaling of Rocky Mountain Area Sawtimber

Donald C. Markstrom and Rudy M. King

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Cubic Foot/Weight Scaling of Rocky Mountain Area Sawtimber

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ABSTRACT

Cubic-foot/weight scaling of short ponderosa pine and white spruce logs required less than half the number of truckloads to be both weighed and stick scaled as compared with the number required for Scribner board-foot/weight scaling. Cubic-foot/weight scaling of long Engelmann spruce and white fir logs resulted in 19% fewer loads to be weighed and stick scaled as compared with the number required for Scribner board-foot/weight scaling. The study showed that ratio weights need to be recalculated depending upon changes in timber size and woods storage time.

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[1] *Headquarters is in Fort Collins, CO in cooperation with Colorado State University*

Cubic Foot/Weight Scaling of Rocky Mountain Area Sawtimber

Donald C. Markstrom and Rudy M. King

Management Implications

Weight scaling of logs from timber sales has been an increasingly important alternative to stick scaling as sawlog size decreases over time. Timber sales measured in board-foot/weight scale, however, have often resulted in highly variable board-foot/weight ratios or conversion factors. The use of cubic-foot measure instead of board-foot measure resulted in lower sampling variation. Consequently, scaling time and costs can be lowered when weight scaling with cubic-foot volume is used rather than board-foot volume.

Introduction

The Forest Service and timber purchasers have recently agreed to begin implementing cubic-foot/weight scaling when estimating log volume to reduce sampling variation in the volume/weight conversion. The present use of board-foot scale has resulted in highly variable board-foot/weight conversion factors.

Pilot testing of cubic-foot/weight scaling began in 1990 with full implementation scheduled for 1994. Part of the effort by Region 2 of the Forest Service was to test cubic scaling on the Black Hills and Rio Grande National Forests. The purpose was to 1) develop information about the volume/weight relationships of the timber used in weight scaling, and 2) develop methods that could accurately estimate truckload volumes based on truckload weights. This was the first test jointly conducted by the Forest Service and industry in the United States. The partners were Region 2, Rocky Mountain Forest and Range Experiment Station, Pope and Talbot Corporation, and Stone Forest Industries.

Research on cubic-foot and board-foot weight scaling and greenwood density has been reported by different authors. Myers (1960) reported research on volume-weight-moisture relationships for ponderosa pine in the Black Hills. He found that the oven-dry weight of the merchantable boles of trees from 6 to 11.5 inches d.b.h. (diameter at breast height) was closely correlated with their cubic volumes. There was no significant difference in density (dry weight per cubic foot) of trees from thinned and unthinned stands nor any correlation between wood density and the following variables: form quotient, age of stump, crown class, crown diameter, crown length, percent of tree length in crown, site index, and stand basal area. In the Black Hills, Landt and Woodfin (1959) reported that the specific gravity averaged 0.398 and greenwood density averaged 57.9 pounds per cubic foot for trees younger than 100 years. The younger trees had a greater greenwood weight per cubic foot because of having a higher proportion of sapwood and, therefore, a higher moisture content than the older trees.

Yerkes (1966) developed regression formulas to predict the density of ponderosa pine sawlogs. Important variables included d.i.b. (diameter inside the bark) of the small end of the logs and average moisture content. In the Black Hills, Mueller and Kovner (1967) reported weight per board-foot ratios by source of logs and percent defect. The pounds per board-foot net scale averaged 10.99 with a 95% confidence level of 0.39. Donnelly and Barger (1977) evaluated three weight scaling methods for southwestern ponderosa pine timber: 1) sample-stick, 2) ratio-weight, and 3) regression-weight scaling. Regression-weight scaling was found to be more precise than the other two. The most precise regression equation that was practical to apply included net-load weight and log count. However, other factors that must be considered were sales area, seasonal change in moisture content, log length mix, and young growth/old growth mix.

Markstrom et al. (1982) found for small ponderosa pine trees in the Black Hills (d.b.h. classes 5, 6, and 7 inches) that wood volume and oven-dry weight of the wood and bark can be reliably estimated from the combined greenwood and bark weight. A total of 97% of the variation in predicting wood volume (cubic feet) from the greenwood and bark weight was accounted for in the trees. Simulation of random truckloads of small roundwood showed that this class of material can be weight scaled by either ratio-weight or regression-weight scaling methods based on a small number of sample loads.

Concerning weight loss from logs left in storage, Yerkes (1967) found that for Black Hills ponderosa pine logs left in woods storage up to 108 days during late summer (July, August, September) weight loss was minor and could be ignored in weight scaling. Fifty short logs lost an average of 5.3% of their beginning

weight. Analysis of logs from storage sites ranging from an open pasture to a dense reproduction thicket did not show a significant effect on weight loss.

Additional research on cubic-foot/weight scaling has been reported in the literature (Cahill 1983; Cahill and Cegelka 1989; Fahey et al. 1981; Fahey and Woodfin 1976; and Plank and Cahill 1984).

Study Objectives

The overall objectives of this study were to 1) test the feasibility of cubic-foot/weight scaling on truckloads of sawlogs, and to 2) identify and evaluate sources of variation that may reduce the reliability of weight scaling.

Prior research has shown that board-foot/weight scaling of ponderosa pine is correlated with the weight and number of logs per truckload (Donnelly and Barger 1977). Additional variables evaluated in this study were 1) tree type/size, 2) woods storage time of logs, 3) percent of cubic volume in defect, 4) amount of substandard material per truckload, and 5) scaling methods.

Study Area and Methods

Black Hills National Forest

A total of 119 truckloads of ponderosa pine and white spruce logs were sampled at the Prospect Administrative Sale in the Black Hills National Forest from October through December 1990. The logs were purchased by the Pope and Talbot Corporation and hauled to their sawmill at Spearfish, South Dakota. After the truckloads were weighed at the sawmill yard, the logs were scaled by Forest Service scalers for both cubic and Scribner volume (fig. 1). All logs on each truckload were counted and scaled for gross-volume and defect-volume. Single segment short logs were scaled with the longest log being 18.0 feet (fig. 2). Both diameters of the logs were measured. Butt logs were measured 4.0 feet from the butt end with a caliper. Cubic volumes were determined with Smalian's formula. The standard materials were logs scaled to a 7.0 inch top; however, the purchaser hauled some logs with top diameters down to 4.0 inches. The cubic volume of this substandard top material with diameters from 7.0 to 4.0 inches was measured and recorded for each truckload.

Figure 1.—Truckload weighing of short logs at Black Hills sawmill yard-log lengths were 18 feet or less.

Figure 2.—Scaling of logs at Black Hills sawmill yard by Forest Service scalers.

Each truckload was grouped into one of the following strata depending upon timber type/size, woods storage time of logs, and scaling method:

1. Younger small ponderosa pine trees cut from a commercially thinned unit (fig. 3). The average d.b.h. was 12.0 inches. The defect was 3.3% Scribner scale and 3.2% cubic scale. Logs were hauled and weighed concurrently with felling and skidding.
2. Older large ponderosa pine and white spruce trees cut from an overstory in aspen stands and meadows (fig. 4). The average d.b.h. of the ponderosa pine was 14.9 inches and the white spruce was 14.3 inches. The defect of the ponderosa pine was 6.7% Scribner scale and 6.0% cubic scale. The defect of the white spruce was 5.6% Scribner scale and 5.7% cubic scale. White spruce was 1.4% of total logs hauled. Logs were hauled and weighed concurrently with felling and skidding.
3. Same as 2 except different logs were hauled and weighed 30 to 35 days after felling and skidding. White spruce was 1.7% of total logs hauled.
4. Same as 2 and 3 except different logs were scaled with 3-P cubic and 3-P Scribner methods instead of conventional cubic and Scribner methods.[2]

[2] *Forest Service Log Scaling Handbook 2409.27-3P.*

Figure 3.—Young smaller ponderosa pine trees typical of those removed in the commercially thinned unit on Black Hills National Forest.

Figure 4.—Older large ponderosa pine trees typical of those removed from an overstory in aspen stands, Black Hills National Forest.

Several statistical methods were used to identify and analyze factors that affected the accuracy of volume/weight predictions. Analysis of variance was initially used to compare homogeneity of variance among the treatment (strata) groups of covariates. Analysis of variance was next used to initially compare response variables among treatment groups. Residuals were plotted against covariates to provide information regarding consistency of covariate relationships among the treatment groups. Correlation analysis were performed on truckload volumes, volumes per pound with truckload weights, and other variables describing individual truckloads. Next, regression models to predict truckload volume were developed and compared with each other. An application of a model to determine the number of sample truckloads for the Prospect Administrative Sale is presented.

Rio Grande National Forest

The timber was harvested from an overstory of Engelmann spruce and white fir at the Love Timber Sale in the Rio Grande National Forest. Trees with d.b.h. ≥10 inches were cut; some with d.b.h. ≥ 11 inches were reserved for wildlife. The logs were cut during September 1991 and immediately hauled to the Stone Forest Industries sawmill at South Fork, Colorado. A total of 39 truckloads were weighed and scaled by the Forest Service. Conventional and 3-P scaling methods were used for Scribner volumes and conventional methods for cubic volumes. The logs on each truckload were counted and scaled for gross- and defect-volume and classified as long logs with length greater than 32 feet (fig. 5). The logs were rolled out on the ground. Both diameters were measured. Butt logs were measured 4.0 feet from the butt end with a caliper. Cubic volumes were determined with Smalian's formula. The logs were scaled to a 7.0 inch top; however, the purchaser hauled some logs with a top to 4.0 inches. The cubic volume of this substandard material was measured and recorded for each truckload. The defect of the logs were 6.4% Scribner scale and 3.3% cubic scale.

Regression models to predict truckload volume were developed and compared with each other. An application of a model to determine the number of sample truckloads for the Love Timber Sale is presented.

Figure 5.—Typical load of spruce and fir long logs 32+ feet from Rio Grande National Forest.

Results and Discussion

Black Hills National Forest

Initial statistical testing of the 3-P and conventional scaling methods indicated that the variances of the two methods were not homogeneous. The variance of net cubic feet per pound (CF/lb) and net Scribner board feet per pound (BF/lb) of the 3-P sample were significantly higher than those of the conventionally scaled truckloads. The variances of the scaling methods were:

Scaling method	n	Variance
CUBIC		CF/lb
3-P	22	490 x 10-9
Conventional	97	160 x 10-9
Scribner		BF/lb
3-P	22	593 x 10-7
Conventional	97	152 x 10-7

Further data analysis was thus limited to the 97 truckloads conventionally scaled. Additional analysis was not performed on the 3-P sample because of the small sample size.

Timber type/size and woods storage time affected the ratio weights of CF/lb, BF/lb, and net cubic feet per pound of all material including substandard material CFA/lb (table 1). The truckloads containing the younger small trees had lower CF/lb and BF/lb but higher CFA/lb than the older large trees. The truckloads with older large trees concurrently-hauled, had a lower CF/lb than those delayed-hauled. The CFA/lb and BF/lb of the truckloads of both currently- and delayed-hauled older large trees were not significantly different.

The net cubic feet per pound increased when the substandard material was included in the volume of the truckload. The volume of substandard material increased with an increase in the number of logs per truckload (correlation coefficient = .881).

CF/lb, CFA/lb, and BF/lb were affected by other load characteristics as indicated by correlation coefficients (table 2). As the number of logs per truckload of a given weight increased, both CF/lb and BF/lb decreased. Both of these probably decreased because substandard material with a top d.i.b. smaller than 7.0 inches was not scaled but was weighed on the trucks. The CFA/lb increased with the number of logs per truckload because the ratio of substandard material to standard material increased in the truckload. Both CF/lb and BF/lb decreased with an increase of defect.

Plotting of residuals (computed as each individual response minus its treatment group mean) against the covariates showed similar covariate relationships among the treatment groups.

Four regression equations were used to estimate truckload volume. Two of the equations used only truckload weights to estimate volume while the other two used both truckload weights and number of logs. Two of the equations were also forced through zero. The four equations were:

$$(1)\quad \hat{v} = b_0 + b_1W$$
$$(2)\quad \hat{v} = b_0 + b_1W + b_2n$$
$$(3)\quad \hat{v} = b_1W$$
$$(4)\quad \hat{v} = b_1W + b_2n$$

where

$\hat{v}$ = estimated truckload net cubic-foot or net board-foot volume
W = weight of logs on truck
n = number of logs on the truckload
b_0, b_1, and b_2 = regression coefficients.

Table 3 summarizes regression equations obtained by fitting the 4 equations to 3 data sets: 1) Net cubic-foot

Table 1. Ratio weights for CF/lb, CFA/lb, and BF/lb of different timber type and woods storage times.[1,2]

Timber type/storage	CF/lb	CFA/lb	BF/lb
	Mean ±1 Std. Dev.		
Younger small trees concurrently hauled	.0121 ± .0004	.0132 ± .0003	.0599 ± .0031
Older large trees concurrently hauled	.0123 ± .0004	.0128 ± .0004	.0630 ± .0037
Older large trees delayed hauled	.0127 ± .0004	.0129 ± .0003	.0650 ± .0032
Total	.0123 ± .0004	.0129 ± .0004	.0625 ± .0039

[1] *Where: 1) CF/lb = net cubic-feet volume per pound of standard material to a 7.0 inch top; 2) CFA/lb = net cubic-feet volume per pound of all material to a 4 inch top; and 3) BF/lb = net Scribner board-foot volume per pound to a 7.0 inch top.*
[2] *Bracketed values are not significantly different at P =.05 (according to Scheffe's test).*

Table 2. Correlation coefficients of CF/lb, CFA/lb, and BF/lb with truckload characteristics.[1]

Truckload characteristics	CF/lb	CFA/lb	BF/lb
Number of logs	-.495[2]	.418[2]	-.593[2]
Net cubic volume of substandard material	-.578[2]	.456[2]	N/A
Percent of volume ponderosa pine	-.050[3]	.137[3]	-.021[3]
Percent of cubic-foot volume defect	-.374[2]	-.233[3]	N/A
Percent of board-foot volume defect	N/A	N/A	N/A

[1] *Where: CF/lb = net cubic-foot volume per pound of standard material to a 7.0 inch top; 2) CFA/lb = net cubic-feet volume per pound of all material to a 4.0 top; and 3) Bf/lb = net Scribner board-foot volume per pound to a 7.0 inch top.*

[2] *Significant at P = .01.*

[3] *Not significant at P = .05.*

volume of standard material (CF-VOL), 2) net cubic-foot volume of all material including substandard material (CFA-VOL), and 3) net Scribner board-foot volume (BF-VOL). The R^2 statistic shows the proportion of variation explained by each equation. The standard error of estimate (SE) measures how precisely the regression equation predicts volume with mean weight (and number of logs). The standard errors can only be compared within each dependent variable group. The R^2 values for board-foot volume are slightly lower than those reported in another study (Donnelly and Barger 1977). Comparison of R^2 and SE values between regressions indicates that counting the logs will generally improve the prediction of truckload volume. Likewise, the SE from the pooled regression analysis indicates that the regression with both weight of logs and number of logs on the truckload was usually more applicable across the different sale areas than just the weight of logs on truckload regression. However, counting of logs on a truck during weighing is considered cumbersome and costly and is generally not practiced.

Analysis of variance of prediction equations with truckload weight alone (table 1) shows that younger small trees concurrently hauled, older large trees concurrently hauled, and older large trees delayed hauled each had significantly different (P =.05) equations (Draper and Smith 1981, extra sum of squares principle). Consequently, different regression equations were determined for each timber condition. The constant term in the equations were not significantly different from zero (P =0.05). The equation $\hat{v} = b_1W$ thus can be used to determine truckload volume. The use of this type of equation with no constant term is used in ratio-weight scaling.

Plotting of truckload volume and weights for the Black Hills logs indicated that volumes of individual truckloads may vary considerably for a given truckload weight (figs. 6-7). The 0.95 confidence interval for individual 60,000 pound loads ranged from approximately 665 to 775 CF-VOL for the younger small trees and 690 to 780 for the older large trees. The confidence interval did not decrease appreciably by including the number of logs in the regression

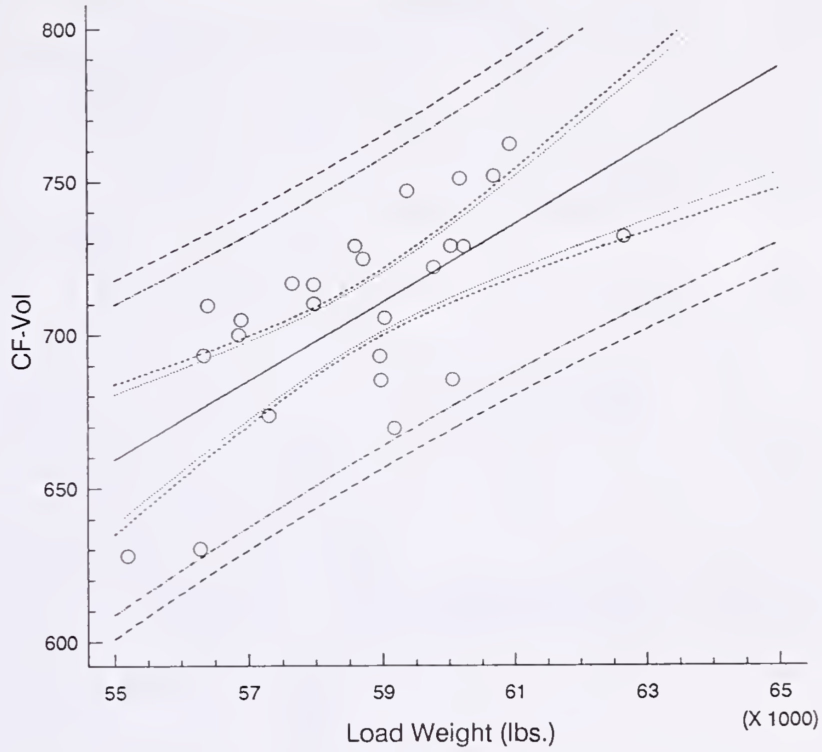

Figure 6.—Scatter diagram and confidence intervals of net cubic-feet volume of standard material versus truckload weight for young small Black Hills ponderosa pine concurrently hauled.

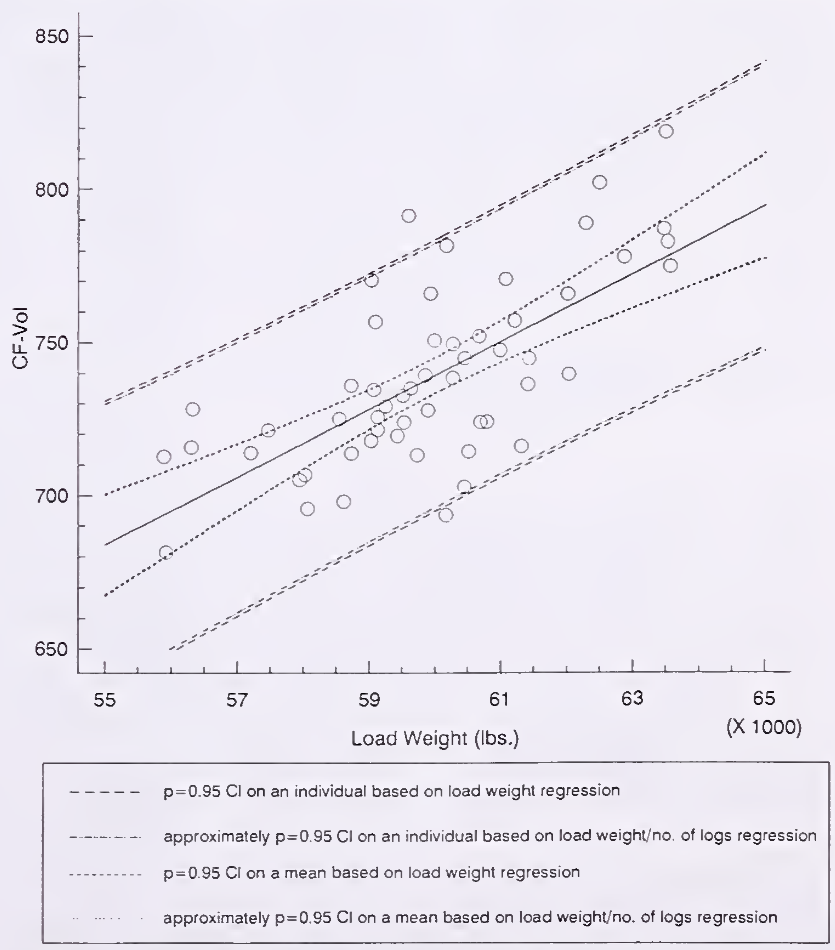

Figure 7.—Scatter diagram and confidence intervals of net cubic-feet volume of standard material versus truckload weight for older large Black Hills ponderosa pine concurrently hauled.

Table 3. Summary of regression of coefficients (b_o, b_1, b_2), their standard errors, and coefficients of determination (R^2) for four equations applied to three data groups for truckloads of Black Hills ponderosa pine and white spruce. The dependent variables are CF-VOL, CFA-VOL, and BF-VOL.

Dependent variable[1]	Data group and equation number	No. of Load	Regression of Coefficients b_o	b_1	b_2	Coefficient of determination R^2	Standard Error of estimate SE	SE[2]
CF-VOL	Younger small trees concurrently-hauled							
	1	25	-44.7[NS3]	.0128	___	.42	26	31
	2	25	10.0[NS]	.0145	-1.2245	.57	22	24
	3	25	___	.0121	___	.45	25	29
	4	25	___	.0147	-1.2212	.61	22	24
	Older large trees concurrently-hauled							
	1	55	73.4[NS]	.0111	___	.47	22	22
	2	55	62.8[NS]	.0119	-.4813	.50	21	22
	3	55	___	.0123	___	.47	22	22
	4	55	___	.0130	-.4904	.51	21	22
	Older large trees delayed-hauled							
	1	17	77.3[NS]	.0114	___	.31	25	32
	2	17	279.1[NS]	.0094	-1.1291[NS]	.40	23	26
	3	17	___	.0127	___	.35	24	33
	4	17	___	.0137	-.8097[NS]	.43	24	26
CFA-VOL	Younger small trees concurrently-hauled							
	1	25	152.2[NS]	.0106	___	.50	18	25
	2	25	126.4[NS]	.0098	.5778[NS]	.55	17	18
	3	25	___	.0132	___	.49	18	26
	4	25	___	.0119	.6194[NS]	.56	17	18
	Older large trees concurrently-hauled							
	1	55	31.7[NS]	.0122	___	.51	22	24
	2	55	34.1[NS]	.0120	.1098[NS]	.51	22	23
	3	55	___	.0128	___	.52	22	24
	4	55	___	.0126	.1048[NS]	.52	22	23
	Older large trees delayed-hauled							
	1	17	120.8[NS]	.0109	___	.38	21	21
	2	17	233.4[NS]	.0098	-.6301[NS]	.40	21	25
	3	17	___	.0129	___	.41	20	20
	4	17	___	.0134	-.3631[NS]	.43	21	24
BF-VOL	Younger small trees concurrently-hauled							
	1	25	-49.3[NS]	.0608	___	.22	189	248
	2	25	460.4[NS]	.0765	-11.4128	.56	142	164
	3	25	___	.0600	___	.25	186	243
	4	25	___	.0840	-11.2617	.59	140	160
	Older large trees concurrently-hauled							
	1	55	670.1[NS]	.0518	___	.15	220	223
	2	55	492.1[NS]	.0659	-8.1102	.31	198	203
	3	55	___	.0630	___	.16	219	221
	4	55	___	.0742	-8.1813	.33	197	203
	Older large trees delayed-hauled							
	1	17	1556.6[NS]	.0388[NS]	___	.04	187	247
	2	17	3369.6[NS]	.0210[NS]	-10.1435	.26	165	182
	3	17	___	.0651	___	.06	186	239
	4	17	___	.0729	-6.2878[NS]	.18	179	187

[1] *Where: 1) CF-VOL = net cubic volume of standard material to a 7.0 inch top, 2) CFA-VOL = net cubic volume of all material to a 4.0 inch top, and 3) BF-VOL = net Scribner board-foot volume to a 7.0 inch top.*
[2] *SE from pooled regression.*
[3] *NS values are not significant at P = .05.*

The number of sample truckloads needed to achieve specified precision of sale-wide estimates can be estimated at the start of the sale using coefficients of variation developed from data in this report. The number of sample truckloads should be recalculated based on sale data after a representative number of truckloads have been sampled. The number of truckloads required in the sample can be calculated as follows:

$$n = \frac{1}{\left(\frac{PE}{CV}\right)^2 \left(\frac{1}{t^2}\right) + \frac{1}{N}}$$

where:

- n = number of truckloads in the sample
- N = estimated total truckloads in sale
- PE = $(E/\bar{x}) \times 100\%$
- CV = $S/\bar{x}$
- $\bar{x}$ = mean of ratio in cubic feet of wood per pound of wood and bark
- t = student's t value; for n larger than 25, t = 2
- E = one half the width of the desired confidence interval; that is, the precision for the sample estimate of the mean in cubic feet of wood per pound of wood and bark.

The following steps illustrate the computation of sample size:

1. Estimate the average truckload ratio weight in cubic feet per pound of wood and bark from experience or presale sample.
   $\bar{x}$= average truckload ratio-weight
   = .0121 cubic feet per pound
2. Estimate truckload ratio standard deviation from experience or presale sample
   S = truckload standard deviation
   = .0004 cubic feet per pound
3. Compute estimated percent coefficient of variation by dividing S by $\bar{x}$.

   $$CV = \frac{S}{\bar{x}} \times 100\% = \frac{.0004}{.0123} \times 100\% = 3.25\%$$

4. Allowable percent error in sale-wide estimate given at 2%.
   PE = 2%
5. Estimate the total number of truckloads in the sale (N) from estimated total sale cruise volume equals 360,000 and average truckload size equals 730 cubic feet.

   $$N = \frac{360000}{730} = 493 \text{ loads}$$

6. Substituting the above quantities and determining the proper t value through trial and error, the number of truckloads to sample (n) was calculated as follows:

   $$n = \frac{1}{\left(\frac{2}{3.25}\right)^2 \left(\frac{1}{(2.201)^2}\right) + \frac{1}{493}} = 12.5$$

The minimum sample size using the next higher whole number is 13. Based upon the 97 truckload sample, the minimum number of truckloads required to be sampled allowing a 2% sale-wide error on the Prospect Administrative Sale were 13 truckloads for net cubic-foot scaling and 34 truckloads for net Scribner board-foot scaling.

The allowable error of 2% signifies the following in terms of buyers and sellers. The truckloads containing 59,500 pounds of greenwood and bark would average 730 cubic feet in the application example. The mean volume of wood on these truckloads would range from 715.4 to 744.6 cubic feet assuming a 2% allowable error at the 95% confidence level. The stumpage value of wood per truckload would be $438.00 assuming wood to be $60.00 per unit. The mean values of the same truckloads based on cubic-value measurements could range from $429.24 to $446.76.

Rio Grande National Forest

The same four regression models used to estimate truckload volume for the Black Hills sample were also used and compared with each other for the Rio Grande sample. Table 4 summarizes the regression estimates for the following four truckload dependent variables:

- CF-VOL - Net cubic-foot volume of standard material to a 7 inch top.
- CFA-VOL - Net cubic-foot volume of all material to a 4 inch top.
- BF-VOL - Net Scribner board-foot volume with conventional scaling of standard material to a 7 inch top.

Comparison of the R^2 and SE values among regressions within each dependent variable group indicates that counting logs will not improve the prediction of truckload volume. The constant term (b_0) and the number of logs per truckload term (b_2) were not statistically significant (P = 0.05) in the regressions. The equation $\hat{v} = b_1 w$ thus can be used to determine truckload volume for Rio Grande Engelmann spruce and white fir as similarly used for Black Hills ponderosa pine.

Based upon the 39 truckload sample, the minimum number of truckloads required to be sampled to achieve sale-wide error of 2% were 29 truckloads for cubic-foot scaling and 36 truckloads for Scribner board-foot scaling using conventional methods.

Table 4. Summary of regression of coefficients (b_0, b_1, b_2), their standard errors, and coefficients of determination (R^2) for four equations applied to truckloads of Rio Grande Engelmann spruce and white fir. The three dependent variables are CF-VOL, CFA-VOL, and BF-VOL.[1]

Dependent variable[1]	Equation number	No. of Load	Regression of Coefficients b_0	b_1	b_2	Coefficient of determination R^2	Standard Error of estimate SE
CF-VOL	1	39	251.1^{NS2}	.0125		.22	56
	2	39	296.2^{NS}	.0142	-2.240^{NS}	.27	55
	3	39	___	.0165		.22	56
	4	39	___	.0188	-2.0066^{NS}	.26	56
CFA-VOL	1	39	203.5^{NS}	.0141		.30	53
	2	39	243.6^{NS}	.0157	-1.9875^{NS}	.33	52
	3	39	___	.0174		.30	53
	4	39	___	.0193	-1.7958^{NS}	.33	52
BF-VOL	1	39	1726.1^{NS}	.0504		.13	309
	2	39	1927.8^{NS}	.0583	-10.0106^{NS}	.17	307
	3	39	___	.0783		.12	312
	4	39	___	.0877	-8.4932	.15	312

[1] Where: 1) CF-VOL = net cubic volume of standard material to a 7.0 inch top, 2) CFA-VOL = net cubic volume of all material to a 4.0 inch top, 3) BF -VOL = net Scriber board-foot volume with conventional scaling of standard material to a 7.0 inch top.
[2] NS values not significant at P = .05.

Conclusions

Cubic-foot/weight scaling of ponderosa pine and white spruce on the Prospect Administrative Sale required less than half the number of truckloads to be scaled as compared with the number required for Scribner board-foot/weight scaling. This reduction in the number of truckloads sampled obviously reduces scaling time and costs. Cubic-foot/weight scaling of Engelmann spruce and white fir logs on the Love Timber Sale resulted in 19% fewer truckloads to be scaled as compared with the number required for Scribner board-foot/weight scaling. Some differences between the Prospect Administrative Sale and Love Timber Sale were species mix and scaling method. The Prospect Administrative Sale was scaled as short logs and the Love Timber Sale as long logs.

The study showed that ratio weights need to be recalculated depending upon changes in timber size and woods storage time. Tree type/size, woods storage time of logs, number of logs per truckload, percent of cubic volume in defect, and the amount of substandard material in a truckload affected the ratio weights. Comparison of the 3-P scaling method with the conventional scaling method was not possible because the variances of the two methods were not homogeneous. Other possible sources of variation in ratio weights not measured in this study were seasonal variation in tree moisture content, and site-related factors. Consequently, the number of sample truckloads from a sale area should be based upon sales data from the area.

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Cubic-foot/weight scaling of short ponderosa pine and white spruce logs required less than half the number of truckloads to be both weighed and stick scaled as compared with the number required for Scribner board-foot/weight scaling. Cubic-foot/weight scaling of long Engelmann spruce and white fir logs resulted in 19% fewer loads to be weighed and stick scaled as compared with the number required for Scribner board-foot/weight scaling. The study showed that ratio weights need to be recalculated depending upon changes in timber size and woods storage time.

Keywords: Cubic foot, weight scaling, truckloads, *Pinus ponderosa, Picea engelmannii, Abies concolor*

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Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

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